Effectiveness of Kaolin Treatment for the Control of the Olive Fruit Fly *Bactrocera oleae* in Tunisian Olive Groves

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ABSTRACT

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The impact of kaolin treatments (Doses D1 = 3 kg/hl and D2 = 5 kg/hl) on the olive fruit fly *Bactrocera oleae* populations was investigated during a three-year study (from 2012 to 2014) in olive grove located in Nabeul: North-Eastern of Tunisia. The results showed that kaolin based-treatment compared to dimethoate, led to a very low level of olive infestation. Kaolin had successfully suppressed *B. oleae* populations and provided season-long pest control. However, D1 and D2 doses had almost similar effects against *B. oleae* populations. Furthermore, kaolin based-treatment seemed to have no adverse effect against parasitic activity and especially that of *Psyttalia concolor*. Eventually, based on the obtained results, it can be concluded that kaolin may be a promising alternative for the control of *B. oleae* in organic olive groves.

Keywords: *Bactrocera oleae*, kaolin, olive, parasitic activity, Tephritidae

The olive tree (*Olea europaea*) is one of the widely grown trees in the Mediterranean countries and is a crop of social and economic importance. The Tunisian olive grove consists of about 67 million trees covering more than 1.7 million hectares with Chemlali being the most grown cultivar in Tunisia and representing more than 60% of the total olive trees (12).

The olive fruit fly, *Bactrocera oleae* (Diptera: Tephritidae), is one of the most devastating insect pests throughout all olive-growing regions particularly in the Mediterranean countries (18, 25, 30, 32). The olive fruit fly is strictly monophagous (20), and the gravid female lays its eggs in fruits. After hatching, the larvae feed and make galleries within the mesocarp which will be subsequently infected with fungi. The affected olive fruits are unsuitable for processing and when used, the quality of the extracted olive oil is sharply reduced leading to a significant decrease in its sensory characteristics and alterations in its quality parameters (decrease of phenol and antioxidant concentrations) (22).

In olive canopies, *B. oleae* is controlled by chemical treatments (26). However, in order to reduce their impact on environment and to insure a safer food supply for consumers, searching for

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alternatives to synthetic pesticides is increasingly needed. Kaolin particle film is frequently used to suppress or control arthropods and disease pests in many agricultural crops (2, 4, 6, 7, 8, 14, 25, 28, 33). Kaolin is a white, fine-grained aluminosilicate mineral $[Al_4Si_4O_{10}(OH)_8]$ (8). It may be used in organic agriculture both as natural mineral fertilizer and as ingredients processing of agricultural origin from organic production. It has the environmental advantage of being an inert product and non-toxic to vertebrates (9).

In olive orchards, kaolin is sprayed on as a protective physical barrier against several pests such as the olive fruit fly (*B. oleae*), the black scale (*Saissetia oleae*) and the olive moth (*Prays oleae*). It is also applied as a repellent and antiovipositional (3, 5, 9, 21).

Hence, the aim of our present study is to evaluate the effect of kaolin, used as a pest control method, against *B. oleae* population based on field experiments in order to determine if kaolin film could protect olive fruits against fly attack. This knowledge is useful for the development of an integrated pest management program in olive groves.

MATERIALS AND METHODS

The experiment was conducted on olive trees cv. Chetoui. The experimental field was located in North-Western part of Tunisia, Nabeul (36°27'50N, 10°42'13E). The trials were performed during 2012, 2013 and 2014 years.

Trees (30-40 years old) were 7 × 7 m spaced. Four individual treatments were evaluated for their effects against *B. oleae* populations. They included an untreated control, two kaolin-based treatments (kaolin applied at two doses: D1 = 3 kg/hl and D2 = 5 kg/hl) and dimethoate 400 g/l (commercial product Perfekthion used at 100 ml/hl). Each individual treatment was repeated on 3 plots (3 replicates). Each plot was composed of 16 trees (4 × 4) and the only 4 trees located in the centre of the plot were monitored and treated. The volume of sprayed suspension ranged between 8 and 10 l/tree. Treated trees were sprayed until drip and were visually inspected to ensure good coverage. The experiment was performed according to a randomized complete block design.

Each year, kaolin sprays were applied once (on August 20) and dimethoate was repeated three times at 15-day interval treatments (on August 20, September 11, and September 27). Spraying of insecticide products started from 20th August, just after the summer heat, when the weather conditions become favorable to the outbreak of the olive fruit fly.

Fruit damage was assessed by sampling fruits from around the whole tree. Fruit samples were collected weekly where 15 olives per tree were picked up randomly from treated and untreated trees. Each olive was examined for *B. oleae* infestation. Infested olives were then dissected under stereomicroscope to determine the developmental instar of the fly and the infestation rate. An assessment of parasitism rate of *B. oleae* larvae and pupae was also monitored and recorded. The formulas used for the calculation of infestation and parasitism rates are provided below.

Infestation rate = (number of infested olives / total number of examined olives) × 100

Parasitism rate = (number of parasitized larvae / total number of examined larvae) × 100

Field olive fly population was monitored by Mac Phail traps baited with Di-Ammonium Phosphate (DAP) solution (3%) since June. Three traps per hectare were placed in the untreated plots. They were attached 1.5 m above the ground at the exterior of the tree canopy and replaced weekly. The number of flies captured per trap was also recorded weekly.

All statistical analyses were performed using SPSS software version 18. Data of field experiments were processed by ANOVA analysis, after transformation using arcsine √x, according to the range of variation of the percentages. Means were separated according to the LSD test at the 5% significance level.

RESULTS

Fig. 1 reveals that the lowest infestation level of olives by *B. oleae* (12.34 ± 1.90%) was recorded during 2012, while the highest one (19.63 ± 3.92%) was noted in 2013 trial. Indeed, in 2012, the infestation values were fairly low throughout the monitoring period. The damage induced by the olive fly did not exceed 26.2% (24^{th} October) in the untreated plots. The year 2013 was characterized by low yield and favorable climatic conditions for the outbreak of the olive fruit fly and such circumstances have prompted a possible migration of the insect to the inland of country (Pers. observations). During 2014, recorded olive production was high and was associated with a relatively high infestation compared to the two previous years where the greatest damage, expressed by an infestation rate of about 36.5%, was recorded on 2^{th} October.

High temperatures and low humidity occurring in August often slowed down *B. oleae* adult flying until the end of summer. At the beginning of September, the suitable temperature and the relatively high humidity enhanced adults' appearance leading, consequently, to an increase in adults' caught in traps till the end of the month (for example 37 adults/trap/week were recorded in September 2013 (data not shown)). In the three-year monitoring, the peaks in *B. oleae* populations were usually observed in October (approaching olive maturity) which coincided with the appearance of the new autumn generations. Then, *B. oleae* population declined progressively with the decrease in temperature (Fig. 1).

Dimethoate was found to be the most effective in rapidly decreasing *B. oleae* infestation levels specially one week after its spray. Unfortunately, this insecticide quickly lost its effectiveness after approximately 15 days where a further increase in infestation rates was noted.

Kaolin based-treatments applied at both tested doses (D1 and D2) clearly reduced olive infestation by *B. oleae* as compared to control plots. Indeed, the reduction rate varied from 7.67 to 90.53% at the end of season for kaolin D1, while for kaolin D2, the reduction rate ranged between 7.11 and 91.59%.

At harvest, the percentages of infested olives noted in all treated plots were very low and varied between 2.67 and 7.33% while that of control plots was above threshold level (estimated as 10 to 15 % for olive oil).

For each experiment and year, a significant difference was noted between different treatments ($F_{3, 39} = 78.22$, $P < 0.0001$; $F_{3, 39} = 139.58$, $P < 0.0001$ and $F_{3, 39} = 84.17$, $P < 0.0001$ for 2012, 2013 and 2014 trials, respectively). Concerning Kaolin based-treatments, there was no significant difference between both doses tested where D1 and D2 had similar effects on *B. oleae* populations. Overall, no significant difference was also observed between kaolin- and Dimethoate-based sprays and both products maintained the olive infestation at a very low level (Infestation rate above 10% in all treated plots two weeks after sprays). However, a significant difference was recorded between kaolin (D1 and D2) and the untreated control ($F_{2, 28}$ = 58.22, P < 0.0001; $F_{2, 28}$ = 79.58, P < 0.0001 and $F_{2, 28}$ = 74.17, P < 0.0001 for 2012, 2013 and 2014 experiments, respectively) based on olive infestation level by *B. oleae*.

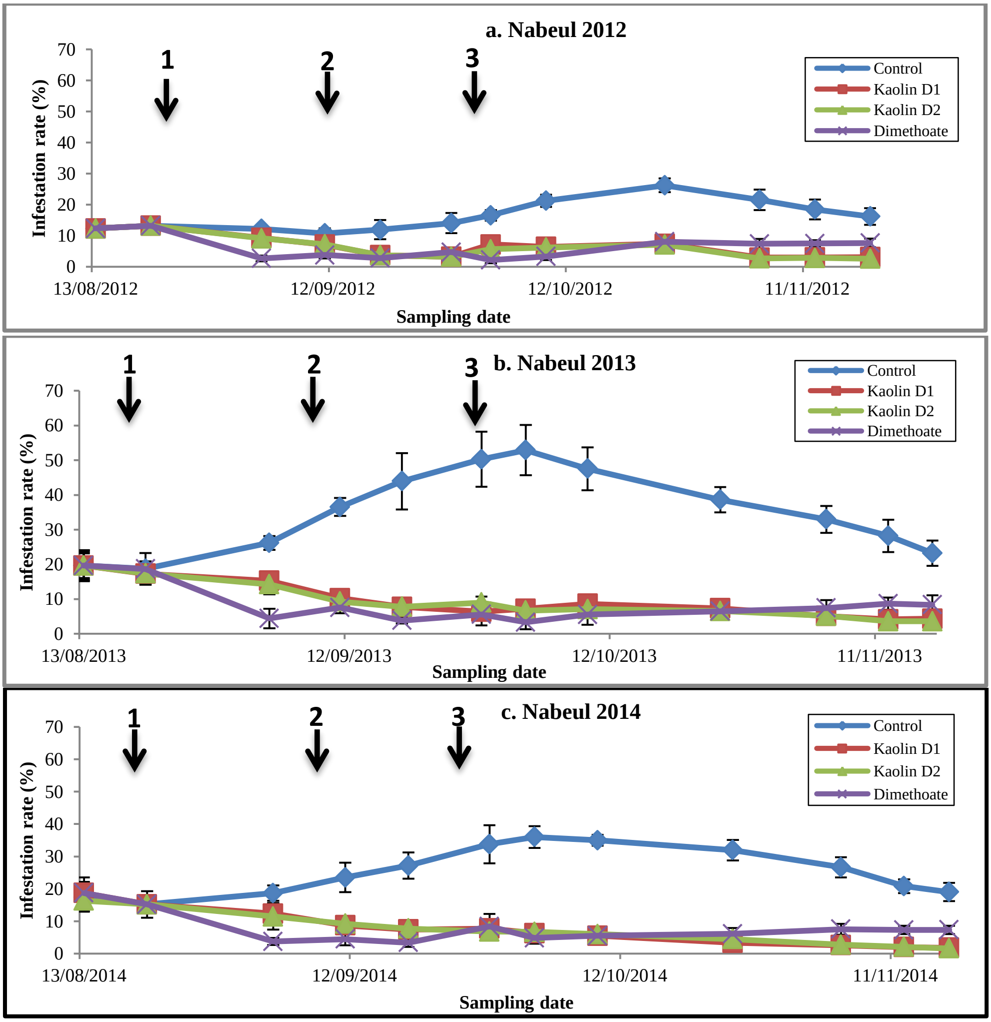

Fig. 1. Variation in olive infestation rates by *Bactrocera oleae* depending on treatments tested in Nabeul noted during 2012, 2013 and 2014 monitoring years. 1: Date of kaolin sprays (August 20); 1, 2, 3: Dates of dimethoate sprays (August 20, September 11, and September 27); Kaolin D1 = 3 kg/hl; Kaolin D2 = 5 kg/hl; Dimethoate dose = 100 ml/hl.

During these field trials and even after several weak precipitations (12th, 16th November 2012: 1 mm and 3 mm, 25th September 2013: 4 mm and 19th November 2014: 1 mm), the kaolin film persisted longer on surfaces of fruits and leaves and despite its coverage reduction, its protective effect persisted till harvest.

The years 2012 and 2013 were characterized by an average parasitic activity which varied between 6.74 and 8.32%. Also, during 2014, high natural mortality rates were recorded within *B. oleae* population which was associated with a major parasitic activity, particularly of *Psyttalia concolor* (Hymenoptera: Braconidae).

In general, kaolin seemed to have no adverse effect against the activity of parasitoids where no significant differences were detected between parasitism rates recorded in untreated control plots and those sprayed with kaolin using doses D1 and D2. However, dimethoate-based treatments had a detrimental effect on natural parasitic activity (Table 1).

Table 1. Variation in parasitism rates depending on tested treatments noted during 2012, 2013 and 2014 monitoring years

Year	Untreated	Kaolin D1	Kaolin D2	Dimethoate
2012	6.74 ± 5.98 a*	6.26 ± 2.95 a	5.9 ± 3.23 a	0.12 ± 1.25 b
2013	8.32 ± 4.79 a	8.97 ± 5.05 a	8.36 ± 3.98 a	0.82 ± 1.49 b
2014	16.26 ± 7.77 a	16.63 ± 6.61 a	14.35 ± 8.68 b	1.91 + 3.74 c

* Mean values in rows followed by the same letter are not significantly different based on LSD test (at $P < 0.05$). D1 = 3 kg/hl; D2 = 5 kg/hl; Dimethoate dose = 100 ml/hl.

DISCUSSION

Efficacy of kaolin sprays compared to dimethoate tested in Nabeul during 2012, 2013 and 2014 for the control of *B. oleae* was evaluated. In Tunisia, summer is generally characterized by high temperatures and low humidity disrupting olive fruit fly population dynamic and increasing abiotic mortality of *B. oleae* (10).

Field trials undertaken during this three-year study indicate that kaolin exhibited great potential to control *B. oleae* populations in olive groves. Also, it provided excellent protection against a wide range of pest insects such as the Mediterranean fruit fly *Ceratitis capitata* on apple (17) and the aphid *Myzus persicae* on peach (11).

Several Tephritid species, including olive fruit fly, use visual, tactile and olfactory cues to find its host plants (1). Prokopy and Haniotakis (24) revealed that *B. oleae*-positive reactions to colors were elicited by wavelengths as they are reflected from the foliage of olive trees and not by olive fruit colors. Therefore, it can be concluded that the bright white color of kaolin-sprayed olive trees could severely disrupt olive fruit fly orientation within the grove. Otherwise, the adult olive fruit flies may fail to recognize kaolin-sprayed trees and alight on the nearby unsprayed trees.

It is plausible that *B. oleae* gravid females that visited kaolin-treated olives were repelled for behavioral reasons due to the tactile unsuitable surface texture of particle film-treated olives (19).

Currently, the most commonly practices used to control Tephritid species are based on synthetic insecticides in bait sprays (13, 15). The lack of significant difference in the infestation percentage between kaolin (once application) and dimethoate based-treatments (three applications) indicated that the kaolin is a suitable alternative to insecticides. However, after the cessation of sprays, the infestation level was slightly increased in the insecticide-treated plots compared with that in the kaolin-treated ones. The systemic activity of dimethoate lasts up to 14 days, but decreased when treated plants were subjected to abiotic stresses (31). Thus, treatment using dimethoate was sufficient to control olive fruit fly if a 2-week spray interval is maintained throughout the season (26), whereas the effect of kaolin particles film clearly remained visible and active till harvest.

Throughout all field trials (2012-2014), kaolin-sprayed foliage and fruits were checked for phytotoxic effects (e.g. leaf burn, leaf drop and fruit bronzing). Visual inspection revealed no adverse effects on plant foliage and fruit until the end of season.

When applied in the field, kaolin can also reduce the abundance and the diversity of canopy arthropods (16, 21, 27). But for the studied parasitoids, particularly *P. concolor*, kaolin based-treatment seemed to have no adverse effect on the activity of these populations. In another study, Porcel et al. (23) did not find any difference in the abundance of adults of *Chrysoperla carnea* (Neuroptera: Chrysopidae) after kaolin applications in olive orchards.

Data from the current study clearly demonstrated the effectiveness of kaolin in controlling *B. oleae* infestations. These promising findings support the need for further investigations on kaolin applications for the control of *B. oleae* in olive groves in large-scale trials in different geographical sites.

RESUME

Gharbi N. et Ben Abdallah S. 2016. Efficacité du traitement au kaolin dans la lutte contre la mouche des olives *Bactrocera oleae* dans des oliveraies tunisiennes. Tunisian Journal of Plant Protection 11: 73-81.

L'impact des traitements au kaolin (Doses 1 = 3 kg / hl et 2 = 5 kg / hl) sur les populations de la mouche des olives *Bactrocera oleae* a été étudié pendant trois années (2012-2014) dans une oliveraie située à Nabeul: Nord-Est de la Tunisie. Les résultats ont montré que le traitement au kaolin, comparé au diméthoate, a contribué à maintenir l'infestation des olives à un niveau très faible. Le traitement au kaolin a réduit suffisamment les populations de *B. oleae* tout le long de la saison. Cependant, les doses D1 et D2 ont eu pratiquement les mêmes effets sur les populations de *B. oleae*. En outre, il semble que les traitements au kaolin soient sans effet néfaste sur l'activité parasitaire et en particulier celle de *Psyttalia concolor*. Finalement, sur la base des résultats obtenus, on peut conclure que le kaolin pourrait être une alternative prometteuse pour la lutte contre *B. oleae* dans les oliveraies biologiques.

Mots clés: Activité parasitaire, *Bactrocera oleae*, kaolin, olives, Tephritidae

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ملخص

الغربي، ناصر وسرين بن عبد الله. 2016. نجاعة المعاملة بالكاولين في مكافحة ذبابة الزيتون *Bactrocera oleae* في حقول الزيتون التونسية. Tunisian Journal of Plant Protection 11: 73-81.

تمت دراسة تأثير المعاملة بالكاولين (الطين المكلس) في جرعتين (الجرعة 1 = 3 كغ/هل و الجرعة 2 = 5 كغ/هل) على مجتمعات ذبابة الزيتون *Bactrocera oleae* خلال ثلاث سنوات (2012-2014) في حقل زيتون بنابل: شمال شرق تونس. أظهرت النتائج أن المعاملة بالكاولين مقارنة بالدايميثويت، ساعدت على الحفاظ على مستوى منخفض جدا من إصابة الزيتون. فالمعاملة بالكاولين ساهمت في تخفيض مجتمعات الآفة *B. oleae* طيلة كامل الموسم، كما تبين أن الجرعتين 1 و 2 لهما تأثيرات مماثلة تقريبا على مجتمعات *B. oleae*. ويبدو أن المعاملة بالكاولين ليس لها أي تأثير سلبي على نشاط التطفل وخاصة لشبه الطفيل *Psyttalia concolor*. اعتمادا على النتائج المتحصل عليها، يمكن استنتاج أن الكاولين يمكن أن تمثل بديلا واعدا للمكافحة *B. oleae* في حقول الزيتون البيولوجية.

كلمات مفتاحية: زيتون، كاولين، نشاط تطفل، Tephritidae، *Bactrocera oleae*

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